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# LIFE CYCLE COST MODEL

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Communications/Automatic Data Processing Laboratory

July 1975

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Recent experience in performing Life Cycle Cost Analyses on single channel tactical radio equipment has shown the need for a complete and computerized LCC model. This report discusses such a model which has been developed by the author. The cost categories and each of their elements are presented initially in broad terms; then the mathematical equations which compute each element are presented. Additionally, a comprehensive discussion of the Learning Curve and the various methods of applying it are presented.

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## 1. INTRODUCTION:

With greater national interest in reduced defense spending, the PEMA dollar will become more difficult to obtain. Therefore, emphasis must be placed on fully justifying new systems or equipment from the cost standpoint.

The purpose of a Life Cycle Cost (LCC) Analysis is to provide a tool for the engineer, manager, or decision maker to use in making correct decisions concerning the introduction of new systems or equipment.

A most important point to recognize is that the outcome of the analysis is greatly influenced by the assumptions made, since these assumptions constitute the major portion of the inputs to the LCC model which computes the costs.

Recent experience in performing LCC analysis has shown that the LCC models generated by Magnavox[1] as part of the Tactical Radio Communication System Concept Study and by the ECOM Comptroller[2] were not ideally suited for doing an LCC analysis on conceptual single channel tactical radio systems or equipment. The primary reason for this is that some cost element computations were based on present day maintenance and technological concepts and did not properly take into account proposed and achievable advancements in the state of the art and changes in the Army's maintenance philosophies. (For instance - the Maganvox model uses a flat rate per failure instead of a different rate for different types of failures; the ECOM model uses a fixed percentage for initial spares and repair parts instead of basing the cost on computed failures IAW TM 38-750-1.)

Since October 1972 two LCC analyses[3,4] have been conducted by Comm/ADP Laboratory on this type of equipment using a prototype consisting of parts of both the Magnavox and ECOM models. Experience obtained from doing these analyses has shown the weaknesses of each model and, in some cases, two different methods of computing the same cost element.

1. Magnavox, "Tactical Radio Communication System Concept Study", Final Report, Volume IV, ECOM-0068-6, 30 June 1972.

2. US Army Electronics Command, "Army Programs Cost Estimating Guide", ECOMP 11-4, Volume 7, 12 June 1972.

3. US Army Electronics Command, "Tactical Radio Communications System Concept Study", Final Report, 8 December 1972.

4. US Army Electronics Command, "Life Cycle Cost Comparison for the COMSEC Implementation of the VHF-FM Subsystem of the Tactical Radio Communication Systems", AMSEL-NL-D, 13 November 1973.

The purpose of this paper is to present the details of a better defined and automated LCC model suited for conceptual or real single channel tactical radio systems or equipment. The model will provide the user with options to select the best method as it relates to the assumptions for computing some of the cost categories. With few or no modifications the model may also be used to study other systems or equipment.

The model was applied in the Communications/Automatic Data Processing Laboratory's support to the Single Channel Ground Airborne Radio System (SINCGARS) Special Task Force in that all the Life Cycle Cost data provided to the task force was generated by the LCC model described in this paper.

This work was done under the Tactical Radio Communication System (TRCS) project, 1S7 62701 AH92.

2. GENERAL.

Life Cycle Cost as defined by AR 37-18 consists of total appropriations for the entire breakdown structure for all cost categories. These cost categories are Research and Development (R&D), Investment Nonrecurring, Investment Recurring, and Operating Costs.

a. R&D - This category includes those costs resulting from applied research, engineering design, analysis, development, and testing. The effort from which these costs derive usually occurs within Exploratory Development, Advanced Development, and Engineering Development.

b. Investment Nonrecurring - This category contains those cost elements which generally occur only once in the production cycle of the system or equipment.

c. Investment Recurring - This category contains those cost elements which occur repeatedly in the production of the system or equipment. It includes the costs incurred in delivery of the system or equipment to the user.

d. Operating Costs - This category includes those direct costs resulting from the operation, maintenance, and consumption of materials and supplies for the system or equipment after acceptance into the Army inventory.

Each cost category is broken down into cost elements, and each element includes both subcategories of contract and in-house. The cost element of each category will be discussed in detail.

Appendix A lists the cost categories and each of their elements. Appendix B gives the complete LCC mathematical model. Appendix C lists the inputs (assumptions) necessary for the model. Appendix D discusses the learning curve, Appendix E discusses the maintenance float requirements problem and, Appendix F shows sample outputs of the LCC model.

3. COST CATEGORIES.

a. Research and Development - Since the system or equipment under consideration is usually conceptual and is planned for initial operational capability (IOC) far in the future (10 years or more) it may be difficult to provide a definite breakdown into the cost elements listed in AR 37-18. Considering further, that R&D costs of radio systems have been shown to constitute only 3-5% of the PEMA investment (by contrast, this figure is 10-20% for other weapons systems such as TOW, UTTAS or Dragon) and less than 2% of the LCC, it is of little value to burden the estimater and the manager with minute details.[5] It is quite sufficient to make a parameter cost estimate for this category, based on previous similar development experiences. The model will consider all R&D elements as lump sum inputs.

(1) Engineering - This effort includes the study, analysis, design development, evaluation and redesign of the item being developed and it also includes all effort in the preparation of specifications, drawings, and the determination of reliability, availability, and maintainability requirements.

(2) Prototype Fabrication - This element includes all the construction and fabrication costs of models fabricated for test, acceptance or delivery.

(3) System Test and Evaluation - This element includes the cost for planning, conducting and support of all testing and the cost of special test equipment and consumable items used in the conduct of the test.

(4) Data - This element includes the handling and publishing cost of drawings, specifications, reports, technical manuals and engineering plans but does not include the engineering effort necessary to formulate these documents since this cost is covered under other elements.

(5) Total Systems Management - This element would appear only on those efforts which are large and complex enough to warrent the overseeing and integrating of the engineering effort. The cost of an operating Project Manager's office is included in this element if one is established during the R&D phase.

(6) Training - This element includes all effort associated with the design and fabrication of training equipment and the cost of training personnel to run the engineering tests.

(7) Producibility Engineering and Planning (PEP) - This element includes the cost associated with any task undertaken to assure producibility of material prior to quantity procurement and includes developing technical data packages, designing special purpose production equipment and tooling, and computer modeling/simulation of the production process.

5. Morgan, E.J., "An Analysis of the Tactical Radio Communications System (TRCS)", Jan 73, report prepared for OCRD, DA, under Task Order 72-443, Battelle Columbus Laboratories, Durham Operations.

Production engineering measures previously defined under Advance Production Engineering (APE), which are principally software oriented, are now in PEP.

b. Investment Nonrecurring - All of the costs incurred in this category have to based on past experience and/or best engineering judgment. The model is designed to accept lump sums for each of the included elements.

(1) Initial Production Facilities Effort (IPF) - This effort includes the cost of the hard tooling and the production line setup necessary to support initial low rate production. The IPF is the production hardware oriented portion of the former Advance Production Engineering (APE). Like the Producibility Engineering and Planning (PEP), the cost should be based on past experience.

(2) Data - This element consists of the initial handling of technical data and preparation of manuals, including the effort required to prepare and publish initial technical orders, technical manuals, etc. Information for computing this element can be found in ECOMP 11-4, Vol. 7.

(3) Tooling - This element includes the planning, engineering, design, fabrication, assembly and installation of tools and test equipment in support of manufacturing the item. These costs should be based on costs incurred on previous contracts or proposals for similar items, and an engineering estimate of the relative amount and complexity of the required tooling.

(4) Instructor Training - This element involves the training of service instructors for a specific system and is usually done by the contractor. The training of instructor personnel for the operation of single channel tactical equipment may not be necessary but with the added complexity of the new equipment, the training of instructors for the maintenance portion must be considered vital and necessary.

(5) Total Systems Management - This element includes the technical and administrative effort performed by the Project Manager and the prime contractors which is related to the total system during the investment nonrecurring phase and which cannot be identified with a specific component of the system. Most often no information is available on any prior contractual efforts in this area, and therefore only the cost related to running a PM office can be considered. In considering some systems the cost may be large enough to warrant a separate PM and be declared a major system as outlined in AR 1000-1; otherwise, the PM cost will be a prorated one based on judgment. Information is available from the ECOM comptroller on operating costs for various sizes of PM offices.

c. Investment Recurring - The major cost element of this category is the procurement cost of the hardware. The "Learning Curve" technique will be used on computing three of the elements in this category and use of it is covered in Appendix D of this report and in ECOMP 11-4, Vol. 3.

(1) Hardware Costs - AR 37-18 defines this as total expenditures necessary to produce the primary and secondary mission equipment. For this LCC model, primary mission equipment is considered the end item (receiver, transmitter, transceiver, etc) and any major supporting components (mounts, antennas, etc.). The batteries or generators needed to power the equipment are considered the secondary mission equipment. Best engineering judgment, past experience and a complete component breakdown if available should be used to determine the cost per first N units. (Note - if the quantity bought is based on the Army Acquisition Objective (AAO) which includes Basis of Issue (BOI) needs, equipment float needs and attrition, then attrition and initial spares costs would be included in the hardware cost element and would not be calculated separately.)

(2) Attrition - This element includes the cost of replacing those end items that are annually destroyed or lost from all causes. The attrition rate is a certain percentage of the number of sets deployed and should be based on past experience. (Note - see paragraph 3c(1) since this cost might already be included in the Hardware Cost.)

(3) Initial Spares and Repair Parts - This element covers the initial supply of spare units (float), repair parts, and batteries necessary to fill the planned pipeline. When the Mean-Time-Between-Failures (MTBF) is not a significant factor in the comparison of alternative choices, a percentage method can be used to compute this element. The factor to use for initial provisioning can be found in ECOM 11-4, Vol. 7. Another method breaks this element into three sub-elements and computes each separately. The initial spares cost of this method is based on an equipment availability constant and computing method discussed in TM 38-715-1 and by Magnavox [1,6].

(4) Support Equipment - This element includes the cost of any common and/or peculiar test equipment necessary to support the equipment/system in the field.

(5) Auxiliary Equipment - This element includes the cost of any government furnished equipment (GFE) necessary to make the equipment/system a complete set before issue. Items such as headsets, mikes, handsets, packframes, etc. are usually GFE items.

(6) First Destination Transportation - This element includes the cost of transporting the procured items from the point of procurement or production to the first destination under Army contract. It is estimated in ECOMP 11-4, Vol. 7 to be 1.5% of the hardware cost.

(7) Initial Training - This element usually includes the training conducted by contractors, Army training centers, service schools, and training teams for the initial crews and direct maintenance personnel required to introduce the system or equipment into the inventory.

6. Magnavox, "Ultra-Reliable VHF-FM Receiver-Transmitter, Life Cycle Cost of Ownership Study and Reliability and Maintainability Study", ECOM-0127-10, February 1971.

Because the equipment considered by this LCC model is usually replacing similar existing equipment or systems, most of the initial training will consist of limited field retraining of personnel (mechanics and operators) by a new equipment training (NET) team. Costs for these teams can be obtained from the Maintenance Directorate.

(8) Engineering Changes - This element includes the estimated cost of any engineering changes that might be done on the equipment during its life cycle. It is usually calculated as a percentage of the total end item cost.

(9) System Test and Evaluation - (Same as 3(a)(3)).

(10) Total Systems Management - This cost element is the same type of cost incurred under the Total Systems Management element in the Investment Nonrecurring category. Either the total amount or a prorated portion of the Project Manager's cost should be used.

d. Operating Costs - This category assumes that no civilian labor will be present in the operation and maintenance personnel elements even though it is possible that during peacetime there will be some direct support and general support maintenance performed by civilians at fixed installations. Civilian labor costs at depot are accounted for in the depot overhaul cost element and in the average maintenance man-hour costs.

(1) Personnel, Pay and Allowances This element includes the cost of the crew and maintenance personnel directly associated with the equipment or system. It should be determined whether or not an operator is required for the equipment or if the equipment is incidental to the operator's mission. (A VHF-FM manpack radio would be considered incidental to the operator's mission, while a HF RATT set mounted in a shelter would not.) The latter is most often the case for single channel tactical radios; therefore, the pay and allowances for operators would not be considered. Salary levels for the required grade levels should be obtained from the latest DOD listing (available from Comptroller). Cost for the maintenance personnel is based on the annual maintenance man hours required and the cost per active maintenance man hour, which is found in ECOMP 11-4, Vol 7.

(2) Personnel Replacement Training - This element covers the cost of training an operator or maintenance person to replace personnel previously trained as needed. Cost of the MOS courses and appropriate turnover rates can be found in ECOMP 11-4, Vol 7.

(3) Consumption - This element consists of the costs of material and utilities consumed or expended in direct operation of the equipment. There are two methods available for computing this element.

The first approach is to estimate the consumption as a percentage of the unit hardware cost similar to the percentage method of computing the initial provisioning. The specific percentage may be based on the judgment of the responsible project engineer. (Typically, past ECOM studies have shown it to be between 5 to 20 percent depending upon the complexity of the equipment. Experience in previous LCC studies[3,4] has shown the factor for single channel tactical radio equipment to be between 5 to 10 percent per annum.) The second approach is to consider battery and repair consumption separately using predicted hours of operation and an MTBF to compute the cost element.

(4) Integrated Logistics Support - This element includes the cost attributable to inventory management and stockage of all the major and minor items of supply for the equipment. This element cost includes the introduction, first year costs, and recurring costs of inventory management and the costs of stockage of the end item, initial spares and repair parts and consumption material. ECOMP 11-4, Vol 7 gives estimating guidance for the introduction, first year and recurring costs. The stockage costs are based on a percentage of the hardware cost, initial provisioning, and consumption costs and these percentages can be obtained from the Cost Analysis Division, Comptroller.

(5) Depot Overhaul - This element covers the cost associated with equipment overhaul estimated as an annual cost for each piece of equipment fielded. It includes labor, materials, and the cost of transporting the equipment to the depot and returning it to operational status. For the type of equipment considered by this LCC model, the overhaul cost is zero, as end items are seldom put on a depot assembly line for overhaul. An exception is the return of an item from several years in the field to be resold under the military assistance program (MAP). However, the depot does overhaul modules and this is considered in the repair costs.

(6) Transportation - This element includes the cost of shipping the equipment to depot for overhaul.

## APPENDIX A

## COST CATEGORIES AND ELEMENTS AND WORK BREAKDOWN STRUCTURE

1. The following is a condensed list of the cost categories and elements used in the Life Cycle Cost Model.

   a. Research and Development

      (1) Engineering

      (2) Prototype Fabrication

      (3) System Test and Evaluation

      (4) Data

      (5) Total Systems Management

      (6) Training

      (7) Producibility Engineering and Planning

   b. Investment Nonrecurring

      (1) Initial Production Facilities Effort

      (2) Data

      (3) Tooling

      (4) Instructor Training

      (5) Total Systems Management

   c. Investment Recurring

      (1) Hardware Cost

      (2) Attrition

      (3) Initial Spares and Repair Parts

      (4) Support Equipment

      (5) Auxiliary Equipment

      (6) First Destination Transportation

      (7) Initial Training

      (8) Engineering Changes

(9) System Test and Evaluation

(10) Total Systems Management

d. Operating

(1) Personnel, Pay and Allowances

(2) Personnel, Replacement Training

(3) Consumption

(4) Integrated Logistics Support

(5) Depot Overhaul

(6) Transportation

2. Figure A-1 shows the cost categories and elements in their appropriate place in the Work Breakdown Structure.

| COST CATEGORY | APPROPRIATION | WORK BREAKDOWN STRUCTURE<br>MAJOR SYSTEM EQUIPMENT | ALL OTHER | INITIAL SPARES & REPAIR PARTS |
|---|---|---|---|---|
| Research & Development | RDTE | Engineering<br>Prototype Fabrication<br>Producibility Engrg & Planning | System Test & Eval<br>Data<br>Training-Contract<br>Total Systems Mgmt | DT/OT Spares |
| Investment Non-Recurring | PEMA | Initial Production Facilities<br>Tooling | Data<br>Instructor Training-<br>Contract | |
| Investment Recurring | PEMA | Hardware Cost<br>Attrition<br>First Dest Trans-Hardware,<br>Attrition, Auxiliary Items<br>Equipment Changes<br>Auxiliary Equipment | Support Equipment<br>System Test & Eval -<br>Contract<br>First Dest Trans-<br>Support Equipment | Initial Spares<br>& Repair Parts<br><br>First Dest Trans -<br>Spares & Repair Parts |
| Investment Recurring | MPA OMA<br>OTHER | | System Test & Eval -<br>In house<br>Total Systems Mgmt<br>Initial Training | |
| Investment Non-Recurring | MPA OMA<br>OTHER | | Total Systems Mgmt<br>Instructor Training -<br>In house | |
| Research & Development | MPA OMA<br>OTHER | | Training - In house<br>System Test & Eval -<br>In house | |
| Operating | OMA MPA<br>OTHER | Pay & Allowances<br>Consumption<br>Integrated Logistics Spt<br>Depot Overhaul<br>Transportation | Replacement & Training | |

FIGURE A-1 WORK STRUCTURE BREAKDOWN

## APPENDIX B

## LCC MODEL

This appendix discusses the LCC model for each cost category. Each component, element and category is given a variable name. Discussion of the learning curve is found in Appendix D. This curve reflects the price/cost reductions that can be expected from large quantity buys of equipment as a result of increased efficiency (learning) by a producer, and of competition between producers.

For simplification all dollar values should be given in constant FY dollars of the same year in which the analysis is being done.

a. Research and Development - Research and Development Total Cost ($RDTOT) as shown in equation (1) is the sum of the engineering ($RDE), prototype fabrication ($RDPF), system test and evaluation ($RDSTE), data ($RDDAT), total systems management ($RDTSM), training ($RDT) and producibility engineering and planning ($RDPED). The training cost is the sum of the cost paid to the contractor ($RDTC) and the cost incurred by the government (call in house) for salaries, TDY, etc. for personnel receiving the training ($RDTH). The prototype fabrication cost ($RDPF) is the sum of the cost for the major equipments ($RDPFE) and the cost of the DT/OT spares ($RDPFS). The system test and evaluation cost ($RDSTE) is the sum of the cost paid to the contractor to assist in the test (RDSTC), the cost incurred by the government for engineer support (RSTIR) which comes from RDT&E funds and the cost paid from OMA funds for troop support (RDSTIO).

$$\$RDTOT = \$RDE + \$RDPF + \$RDSTE + \$RDDAT + \$RDTSM + \$RDT + \$RDPEP \quad (1)$$

All cost elements are considered as lump sum inputs to the model.

b. Investment Nonrecurring - The total Investment Nonrecurring Cost ($INTOT) as shown in equation (2) is the sum of the initial production facilities ($INIPF), data ($INDAT), tooling ($INTOL), instructor training ($INITR), and total systems management ($INTSM) costs. The instructor training is the sum of costs paid to the contractor ($ITRC) and the cost incurred by the government for salaries, TDY, etc. ($ITRM) of personnel receiving the training.

$$\$INTOT = \$INIPF + \$INDAT + \$INTOL + INITR + \$INTSM \quad (2)$$

All costs elements are considered as lump sum inputs to the model.

c. Investment Recurring - The total Investment Recurring Cost ($IRTOT) as shown in equation (3) is the sum of the hardware cost ($HC), attrition ($ATC), initial spares and repair parts ($ISRPC), support equipment ($SE), auxiliary items ($AUX), first destination transportation ($FDC), initial training ($ITNET), engineering changes ($EC), system test and evaluation ($RSTE), and total systems management ($IRTSM).

$\$IRTOT = \$HC + \$ATC + \$ISRPC + \$SE + \$AUX + \$FDC + \$ITNET +$

$$\$EC + \$RSTE + \$IRTSM \qquad (3)$$

(1) Hardware Cost - The hardware cost is the sum of the primary and secondary mission equipment costs which include the total unit cost ($TUC), major supporting components cost ($MSC), and the battery (power) costs ($BTYC) as shown in equation (4).

(a) Total Unit Cost - The total unit cost, equation (5), is the product of the quantity of equipment bought (QB) to satisfy the objective and the average unit cost (AUC), where the AUC, equation (6), is equal to the product of the cost of the first unit (A) and the cumulative average factor (CAF). Computation of cumulative average factors, exponent of the learning curve, and average unit costs are discussed in detail in Appendix D. If the second option is used to compute the initial spares and repair parts, the AUC is computed from a CAF based on the QB and the quantity of units required to satisfy the float (see (2)(a)).

$$\$HC = \$TUC + \$MSC + \$BYTC \qquad (4)$$

$$\$TUC = QB \times AUC \qquad (5)$$

$$AUC = C\$U \times CAF/CAF_Q \qquad (6)$$

Where Q is the number of sets that C$U is based on.

(b) Battery Costs - The battery cost, equation (7), is the cost associated with providing the necessary batteries to equip all the manpack sets which are deployed. It is the product of the quantity of manpack sets bought (QBM), cost per battery (C$B, and percentage of sets deployed (PD).

$$\$BTYC = QBM \times C\$B \times PD \qquad (7)$$

(2) Attrition - The cost, equation (8), due to attrition ($ATC) is based on an attrition rate per year (ATR), the number of years of service for the equipment (NRYS), and the average unit cost. The CAF used to compute the AUC is calculated by considering the number of units needed to satisfy the attrition requirements as an add on lot requirement to the hardware units (QB + UFA). This means the CAF is computed using the first unit of the lot as a = QB + UFA + 1 and the last unit of the lot being b = a + RSA. The total number of sets lost due to attrition (RSA) is given by equation (9).

$$\$ATC = RSA \times AUC \qquad (8)$$

$$\text{where } RSA = QB \times PD \times ATR \times NRYS \qquad (9)$$

(3) Initial Spares and Repair Parts - There are two options available for computing the initial spares and repair parts cost. The first method, equation (10), is the result of the product of the initial provisioning factor (PFI) and the hardware cost.

$$\$ISRPC = PFI \times \$HC \tag{10}$$

(a) Initial Spare Equipment - The initial spare equipment cost ($ISE), equation (13), is the product of the units of equipment (float), to assure availability a given percentage of the time (UFA), equation (12), and the average unit cost (AUC). The UFA is dependent upon the average units failed (AUF) and the equipment availability constant (EAC). The equipment availability constant is

| AVAILABILITY | EAC |
|---|---|
| 75% | .67 |
| 85% | 1.04 |
| 95% | 1.65 |
| 99.0% | 2.33 |

where most analyses use the EAC for 85% when considering electronic equipment. The average unit failure is dependent on the hours of operation per day/wartime (HOW) period (days) required to setup the supply pipeline to the direct support level, or the lowest level where floats would be stocked, at onset of a wartime emergency (PS1), the quantity of sets deployed, and the MTBF, equation (11).

$$AUF = HOW \times PS1 \times QB \times PD/MTBF \tag{11}$$

$$UFA = AUF + EAC\sqrt{AUF} \tag{12}$$

$$\$ISE = UFA \times AUC \tag{13}$$

(b) Initial Spare Batteries - The initial stock of batteries, equation (14), includes the cost of providing a battery float ($BTYF) to support the deployed sets in a peacetime environment, and the cost of maintaining a battery reserve ($BTYR) for a wartime emergency. The battery float cost, equation (15), is based on the number of sets deployed, hours of operation per day/peacetime (HOP), cost per battery (C$B), the battery life in hours (BTYL), and the number of available or operating man-days per year (DAY) (normally 260), and the number of months of peacetime stockage required (BTYSP). The battery reserve cost, equation (16) is similarly dependent as the battery float cost except the time of operation is for wartime (HOW) and the number of months stockage (BTYSW) is different.

$$\$ISB = \$BTYF + \$BTYR \tag{14}$$

$$\$BTYF = QBM \times PD \times \frac{HOP \times DAY}{12 \times BTYL} \times BTYSP \times C\$B \tag{15}$$

$$\$BTYR = QBM \times PD \times \frac{HOW \times DAY}{12 \times BTYL} \times BRYSW \times C\$B \qquad (16)$$

(c) Initial Stockage of Repair Parts - There are two methods available for computing the cost of the initial stockage of repair parts ($RPC). The first method equation (17) assumes that all repair work (replacement of parts, models), etc) is done at one level of maintenance. This method is dependent on the average cost per failure ($F) and the time required to setup the supply pipeline to the appropriate maintenance level (PSSI). This method will seldom be encountered with single channel tactical radios.

$$\$RPC = QB \times PD \times PSSI \times C\$F \times HOW/MTBF \qquad (17)$$

The second method, equation (20), considers that the equipment will be made up of replaceable modules or boards containing hybrids and/or parts, with the replacement and repair of these hybrids being accomplished at a depot level. The replacement of the modules or boards occur at a lower level of maintenance. The modules/boards repair parts costs ($HPC), equation (19), are similar to equation (17). PS2 is the time required to setup the supply pipeline to the appropriate maintenance level, where the modules would be stocked, PS3 is the time required to tool up and restock parts at the depot, AMC is the average module cost, and APC is the average part/hybrid cost when AMC and APC are a percentage of the AUC.

$$\$MPC = HOW \times QB \times PD \times PS2 \times AMC \times AUC/MTBF \qquad (18)$$

$$\$HPC = HOW \times QB \times PD \times PS3 \times APC \times AUC/MTBF \qquad (19)$$

$$\$RPC = \$MPC + \$HPC \qquad (20)$$

(4) Support Equipment - The support equipment cost ($SE) is a lump sum input cost of the peculiar and common test equipments necessary to support the equipment/system in the field.

(5) Auxiliary Equipment - The auxiliary equipment cost ($AUX) is a lump sum input cost of any government furnished equipment (GFE) necessary to complete the end item or set such as pack frames, handsets, mikes, etc.

(6) First Destination Transportation - The total first destination cost is the sum of transportation costs for shipping the hardware, attrition items, auxiliary items, support equipment and initial spares and repair parts. It is usually calculated as 1.5% of the cost of each element.

(7) Initial Training - The initial training ($ITNET) is a lump sum input.

(8) Engineering Changes - The total engineering change as shown in equation (21) is calculated as 2% of the total unit cost plus 2% of the attrition cost.

$$\text{\$EC} = (\text{\$TUC} + \text{\$ATC}) \times .02 \qquad (21)$$

(9) System Test and Evaluation - The system test and evaluation cost ($RSTE) is the sum of the contract cost ($RSTEC) and the in house cost ($RSTEH). Both are lump sum inputs.

(10) Total Systems Management - The total systems management cost ($IRTSM) is a lump sum input.

d. Operating Cost - As shown in equation (22), the operating cost ($OCTOT) is the sum of pay and allowances ($ANPAY), replacement training ($RTC), and depot overhaul ($TDOC) plus the consumption ($CONC), integrated logistics support ($ILSC), and transportation ($TRANS).

$$\text{\$OCTOT} = \text{\$ANPAY} + \text{\$RTC} + \text{\$TDOC} + \text{\$CONC} + \text{\$ILSC} + \text{\$TRANS} \qquad (22)$$

(1) Pay and Allowances - The annual pay and allowances cost, equation (26), consists of pay and allowances for operators of the equipment ($ANOP) and maintenance personnel ($ANME). The $ANOP is calculated by multiplying the number of operators (NOP) required by the annual pay and allowance for the operator's grade level ($OPAY).

$$\text{\$ANOP} = \text{NOP} \times \text{\$OPAY} \qquad (23)$$

The $ANME is calculated by multiplying the cost per active maintenance man hour (AMH$) by the total annual maintenance hours (AMMH) required, equation (25). The AMMH is dependent on the MTBF, mean-time-to-repair (MTTR), and the hours of operation per year and number of equipments deployed, equation (24).

$$\text{AMMH} = \text{HOP} \times \text{QB} \times \text{PD} \times \text{DAY} \times \text{MTTR/MTBF} \qquad (24)$$

$$\text{\$ANME} = \text{AMMH} \times \text{AMH\$} \qquad (25)$$

$$\text{\$ANPAY} = (\text{\$ANOP} + \text{\$ANME}) \times \text{NRYS} \qquad (26)$$

(2) Replacement Training - The replacement training cost ($RTC) for operators and maintenance are dependent upon the associated turnover rates (TR), number of personnel required, and the course costs. The course cost (C$C) is a lump sum input. The $RTC, equation (27), is the sum of operator replacement training cost ($ORT) and the mechanic replacement training cost ($MRT).

$$\text{\$RTC} = (\text{\$ORT} + \text{\$MRT}) \times \text{NRYS} \qquad (27)$$

$$\text{where } \text{\$ORT} = \text{NOP} \times \text{TR} \times \text{C\$C} \qquad (28)$$

$$\text{\$MRT} = \text{TR(M)} \times \text{C\$C(M)} \times \text{NME} \qquad (29)$$

$$\text{and } \text{NME} = \text{AMMH}/1720 \qquad (30)$$

(3) Consumption - The consumption can be computed by two methods. The first method computes the consumption as a certain percentage of the hardware cost for the first year, and a second percentage for the remaining years as shown in equation (31).

$$\$CONC = (.10 + .05\ (NYRS-1)\ \times \$HC \qquad (31)$$

The second method computes the cost as the sum of the repair parts consumption ($ANRPC) and the battery consumption ($ANBAT).

$$\$ANBAT = HOP \times DAY \times QBM \times PD \times C\$B/BTYL \qquad (32)$$

$$\$ANRPC = HOP \times DAY \times QB \times PD \times APC \times AUC/MTBF \qquad (33)$$

$$\$CONC = (\$ANBAT + \$ANRPC) \times NYRS \qquad (34)$$

(4) Integrated Logistics Support - (NRLI) plus the sum of the consumption costs ($CONC), initial repair parts ($RPC) and initial battery stockage ($ISB) times the integrated logistics support factor (FILS) plus the product of the end item floats cost ($ISE) times the number of years (NRYS) times the general storage cost factor (GSCF).

$$\$ILSC = (\$INTRO + \$LYRC + (NRYS -1) \times \$RC) \times NRLI + (\$CONC + \$ISB + \$RPC) \times FILS + (\$ISE \times NRYS \times GSCF) \qquad (35)$$

At present the integrated logistics support factor is between 23% and 33% and the general storage cost factor is 1%.

(5) Depot Overhaul - The depot overhaul cost per unit per year can be computed from

$$\$DOC = (0.809)\ (DOR)\ (AUC)^{.881} \qquad (36)$$

where DOR = depot overhaul rate = 1/MTBO (mean-time-between-overhauls)

$$\$TDOC = DOC \times QB \times PD \times NYRS \qquad (37)$$

(6) Transportation - The transportation cost ($TRANS) is calculated as 1.5% of the Total Unit Cost (TUC) of the deployed sets.

## APPENDIX C

## MODEL VARIABLES

The following variables are used in the Life Cycle Model (* Indicates the variable is an input.)

| | |
|---|---|
| *AMC | Average module/board cost given as a percentage of the AUC |
| AMMH | Annual maintenance hours |
| *AMH$ | Cost per active maintenance man-hour |
| *APC | Average part/hybrid cost given as a percentage of the AUC |
| *ATR | Annual attrition rate |
| AUC | Average unit cost |
| AUF | Average units failing |
| *BTYL | Battery life |
| *BTYSP | Required peacetime battery stockage level |
| *BTYSW | Required wartime battery stockage level |
| CAF | Cumulative average factor |
| CAFQ | Cumulative average factor for Q units |
| *C$B | Average cost per battery |
| C$C | Replacement training course cost |
| *C$F | Average cost per failure |
| *C$U | Average cost per unit for the 1st Q units |
| *DAY | Number of available or operating man-days per year |
| *DOR | Depot overhaul rate |
| *EAC | Equipment availability constant |

| | |
|---|---|
| *FDC | First destination transportation factor |
| *FILS | Integrated logistics support factor |
| *GSCF | General storage cost factor |
| *HOP | Hours of operation per day/peacetime |
| *HOW | Hours of operation per day/wartime |
| *MTBF | Mean-time-between-failures |
| *MTTR | Mean-time-to-repair, not including logistics time |
| *NOP | Number of operators |
| *NRLI | Number of line items supported |
| *NRWO | Length of the operator course in weeks |
| *NRWM | Length of the maintenance course in weeks |
| *NRYS | Number of years |
| *OPAY | Operator pay |
| *PD | Percentage deployed |
| *PFI | Initial provisioning factor |
| *PS1 | Period required to set up supply pipeline to lowest support level, where floats are stocked, at onset of wartime emergency |
| *PS2 | Period required to set up pipeline to the lowest maintenance level where modules are stocked |
| *PS3 | Period required to set up tooling and restock parts at the depot |
| *PSS1 | Period required to set up pipeline to the lowest appropriate maintenance level for the percentage method |
| *Q | Number of sets the C$U is based on |
| *QB | Quantity bought |

| | |
|---|---|
| *QBM | Quantity of manpacks bought |
| *QMAAO | Quantity required to complete the AAO at the start |
| RSA | Number of sets lost due to attrition |
| *TRO | Turnover rate, operator |
| *TRM | Turnover rate, maintenance personnel |
| UFA | Units to assure availability a given percent of time |
| $ANBAT | Annual battery consumption cost |
| $ANME | Annual maintenance personnel cost |
| $ANOP | Annual operator cost, pay and allowances |
| $ANPAY | Annual operating cost, personnel |
| $ANRPC | Annual repair parts cost |
| $ATC | Attrition cost |
| *$AUX | Auxiliary items cost, investment recurring |
| $BTYC | Battery cost, initial issue |
| $BTYF | Battery float cost |
| $BTYR | Battery reserve cost |
| $CONC | Consumption cost |
| $DOC | Depot overhaul cost per unit |
| $EC | Engineering changes, investment recurring |
| $FDC | First destination transportation cost |
| $FDCH | $FDC, hardware |
| $FDCS | $FDC, initial spares and repair parts |

| | |
|---|---|
| $HC | Hardware cost |
| $HPC | Hybrid/parts cost, initial stockage |
| $INTOT | Total investment nonrecurring cost |
| $ILSC | Integrated logistics support cost |
| *$INDAT | Data, investment nonrecurring |
| *$INIPF | Initial production facilities, investment nonrecurring |
| $INITR | Instructor training, investment nonrecurring |
| *$INTOL | Tooling, investment nonrecurring |
| *$INTRO | Introduction cost, integrated logistics support |
| *$INTSM | Total system management, investment nonrecurring |
| $IRTOT | Total investment recurring cost |
| *$IRTSM | Total system management, investment recurring |
| $ISB | Initial spare batteries cost |
| $ISE | Initial spare equipment cost |
| $ISRPC | Initial spares and repair parts cost |
| *$ITNET | Initial training costs, investment recurring |
| *$ITRC | Instructor training, contract, investment nonrecurring |
| *$ITRH | Instructor training, in house, investment nonrecurring |
| $MPC | Module parts cost, initial stockage |
| $MRT | Replacement training cost, maintenance personnel |
| *$MSC | Major supporting components cost |
| $OCTOT | Total operating cost |
| $ORT | Replacement training cost, operator |
| *$RDDAT | Data, R&D |
| *$RDE | Engineering, R&D |

| | |
|---|---|
| *$RDPEP | Producibility engineering and planning, R&D |
| *$RDPF | Prototype fabrication, R&D |
| *$RDSTE | System test and evaluation, R&D |
| $RDT | Training, R&D |
| *$RDTC | Training, contract, R&D |
| *$RDTH | Training, in-house, R&D |
| $RDTOT | R&D total cost |
| *$RDTSM | Total system management, R&D |
| *$RC | Recurring cost, integrated logistics support |
| $RPC | Repair parts cost, initial stockage |
| $RSTE | System test and evaluation cost, investment recurring |
| *$RSTEC | System test and evaluation cost, contract, investment recurring |
| *$RSTEH | System test and evaluation cost, in-house, investment recurring |
| $RTC | Total replacement training cost |
| *$SE | Support equipment cost, investment recurring |
| $TDOC | Total depot overhaul cost |
| $TRANS | Transportation cost of shipping equipment to depot for overhaul |
| $TUC | Total unit cost |
| *$1YRS | First year cost, integrated logistics support |

## APPENDIX D

## THE LEARNING CURVE

The definition of the Learning or Experience Curve is as the total quantity of units produced doubles, the cost or man-hours required to produce the last unit of this double quantity will be reduced by a constant percentage. Stated mathematically if $Y(x)$ is the cost of the xth unit produced and $Y(2x)$ is the cost of the last unit of the doubled quantity, then the ratio of ¢(x)/$Y(2x)$ is a constant.[7] Some factors which contribute to the decline of the unit cost as cumulative production increases are familarity with the job due to repetition, development of more efficient tools, machines or procedures, and lower cost of materials due to increased demand. However, it should be remembered that there is some point in production beyond which there is no more reduction in cost. This is the point where the unit cost is equal to the cost of the labor and materials (plus burden). The cessation of cost reductions is at the indeterminant point where productivity can no longer be increased or a given production process reaches a point where marginal cost is equal to marginal revenue. The purpose of this appendix is to explain the use of the learning curve in computing the average unit cost (AUC) and the total unit cost (TUC). Four methods of computation are discussed and two of the methods are explained by relating the statistical approach to integral calculus.

It was found from analysis of empirical data that the learning curve could be represented by equation 1 where Y is the cost per unit, A is the cost of the first unit, and X is the cumulative units produced.[7,8] B is the exponent of the slope where the slope in percent is equal to $2^B \times 100$ as shown in equation 2. For any slope less than 100% B will always be negative and can be computed for any learning curve from equation 3.

$$Y = AX^B \tag{1}$$

$$\% \text{ slope} = 2^B \times 100\% \tag{2}$$

$$B = \frac{\ln\ (\text{slope percent} \times 10^{-2})}{\ln 2}. \tag{3}$$

Equation 1 plots on an arithmetic graph as a hyperbolic curve and on a logarithmic (log-log) graph as a straight line (see figures D-1 and D-2). It is very difficult to forecast or extrapolate a hyperbolic curve and an arithmetic curve lacks the capability of adequately portraying extended numbers of units on the X axis: therefore, the straight-line log-log curve is used extensively for the methods discussed.

7. US Army Electronics Command, "Army Programs Basic Techniques of the Learning Curve", ECOM 11-5, Volume 3, 25 June 1971.

8. US Army Missile Command, "The Experience Curve Table", Volume I & II, Redstone Arsenal, Alabama, September 1962.

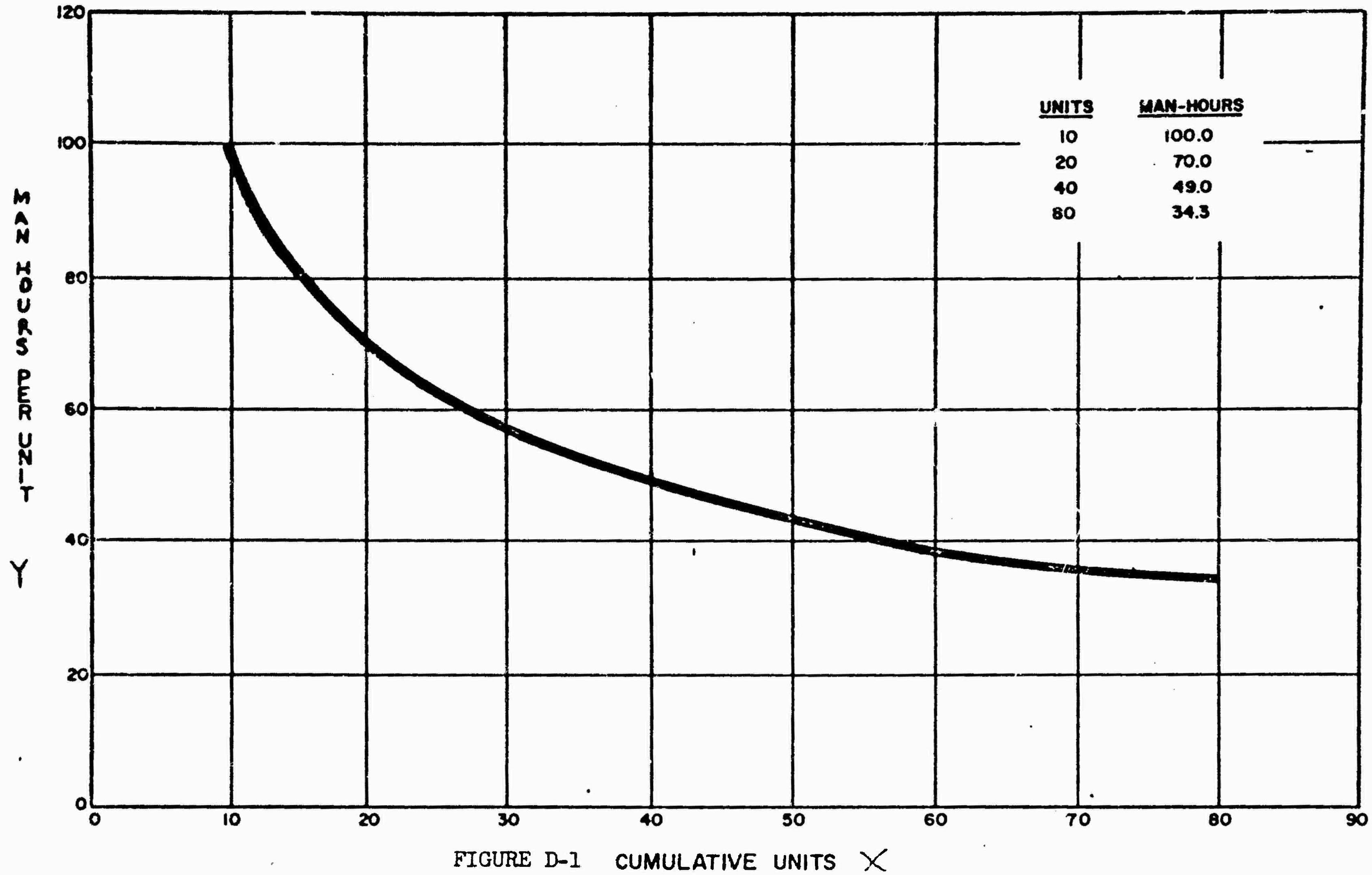
UNITS
MAN-HOURS
10
100.0
20
70.0
40
49.0
80
34.3
0
20
40
60
80
100
120
MAN HOURS PER UNIT
Y
0
10
20
30
40
50
60
70
80
90
CUMULATIVE UNITS
X

FIGURE D-1

| X | Y |
| --- | --- |
| 10 | 100.0 |
| 20 | 70.0 |
| 40 | 49.0 |
| 80 | 34.3 |

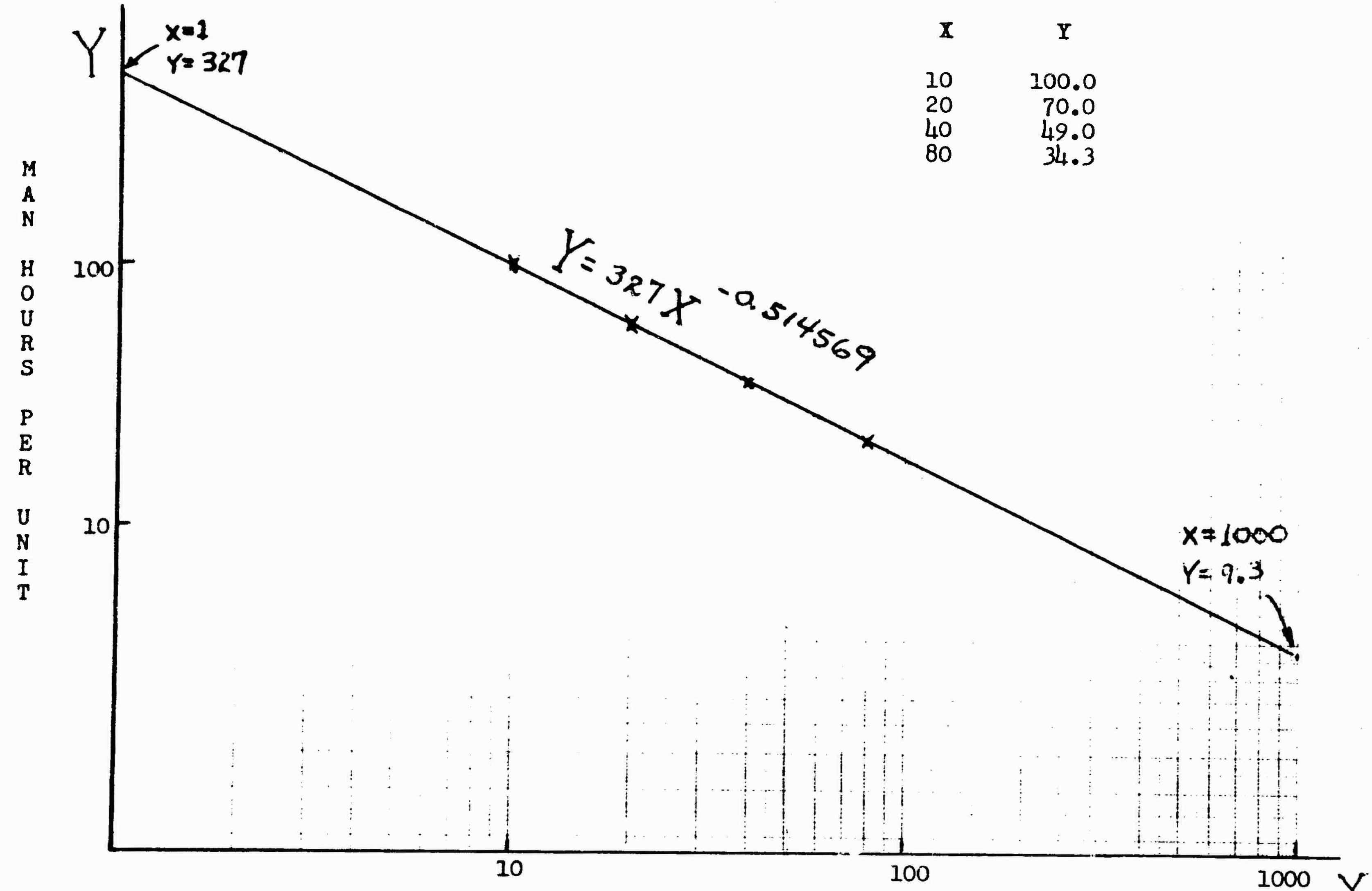


FIGURE D-2 CUMULATIVE UNITS

SUMMATION METHOD

The ratio of $Y/A = X^B$ is called the unit factor and it is the ratio of the cost for the xth unit to the cost of the first unit. The total unit cost (TUC) of n units can be obtained by using the learning curve. The TUC is simply the sum of all the Y's from x = a (first unit of the lot) to x = b (last unit of the lot) where b = n + a - 1 and is stated mathematically as

$$TUC = \sum_{x=a}^{b} Y(x) = \sum_{x=a}^{b} AX^B \qquad (4)$$

Factoring the constant A from the summation gives

$$TUC = A \sum_{x=a}^{b} X^B \qquad (5)$$

The factor $\sum_{x=a}^{b} X^B$ is called the cumulative total factor (CTF) and it is the sum of all the unit factors up to and including the unit factor for the nth unit.

By dividing the CTF by n as in equation 6 we get the cumulative average factor

$$CAF = \frac{CTF}{n} = \frac{\sum_{x=a}^{b} X^B}{n} \qquad (6)$$

This CAF is used in the model to calculate the average unit cost (AUC) which in turn is used to compute the total unit cost (equation 8).

$$AUC = A \times CAF \qquad (7)$$

$$TUC = AUC \times QB \qquad (8)$$

where QB is in quantity of equipments bought.

"EXPERIENCE CURVE TABLES" METHOD

The method of using the CAF or the CTF gives the most accurate results of the four methods. The computer sub-routine of the model is able to compute the CAF fast and accurately but this task would take an enormous amount of time to do by hand for a sizable lot. Redstone Arsenal [7] has developed "The Experience Curve Tables" to simplify hand computations. The tables consist of four columns for each slope ranging from 67% to 99%. The first column consists of the cumulative units (n) up to 5000; the second column contains the cumulative total factors (CTF); the third column contains the cumulative average factors (CAF); and the fourth column contains the unit factors.

7. US Army Missile Command, "The Experience Curve Table", Volume I & II, Redstone Arsenal, Alabama, September 1962.

The tables also give extension factors for 4K-40K units; however, experience has shown that the LCC model must in some instances handle quantities greater than 40K which make the tables unusable. The methods to be discussed can be done completely by hand using a slide rule, log tables or a desk calculator. The two methods are fairly rapid and reasonably accurate.

## INTEGRATION METHOD

Since each point on the curve in figure 2 represents a unit cost for a particular unit n within the interval $a \leq n \leq b$, the total unit cost (TUC), as previously stated, can be obtained by summing all the points on the curve for $a \leq n \leq b$ as

$$TUC = \sum_{x=a}^{b} Y(x) = \sum_{x=a}^{b} f(x) \qquad (9)$$

where $f(x) = AX^{B}$ and is continuous and single valued in the interval (a,b).

Let us take the function $y = f(x)$ and divide this interval (a,b) into n sub-intervals by n-1 division points $x_1, x_2, x_3, \ldots, x_{n-1}$ (figure 3) where $a < x_1 < x_2 \ldots < x_{n-1} < b$. For convenience of notation let $x_0 = a$ and $x_n = b$. Let $\xi_n$ denote any point in or at the end of the $k^{th}$ sub-interval $(x_{k-1}, x_k)$ where k is any one of the numbers 1,2,3,....n so that $x_{k-1} \leq \xi_k \leq x_k$ for each value of k from 1 to n. Let $\Delta x_k$ denote the length of the $k^{th}$ interval so that $\Delta x_k = x_k - x_k-1$.

Forming the sum we get

$$S_n = f(\xi_1)\Delta x_1 + f(\xi_2)\Delta x_2 + \ldots + f(\xi_n)\Delta x_n. \qquad (10)$$

Which can be notated as

$$S_n = \sum_{k=1}^{n} f(\xi_k)\Delta x_k. \qquad (11)$$

Since limit $S_n$ exists as $n \to \infty$ and each $\Delta x_k \to 0$ and the limit is the same for all modes of subdivision of the interval (a,b) then by definition(8) of the definite integral of f(x) we get

$$\lim_{n\to\infty} \sum_{k=1}^{n} f(\xi_k)\Delta x_k = \int_a^b f(x)\,dx. \qquad (12)$$

Let us now take the interval (a,b) and divide it into n sub-intervals $\Delta x_k$ ($k = 1,2,3,\ldots n$) and on each sub-interval $\Delta x_k$ select an arbitrary point $\xi_k$ as shown in figure 4. Using each sub-intervals $\Delta x_k$ as a base, construct a rectangle with altitude $f(\xi_k)$. The sum of these rectangles is represented by

$$S_n = \sum_{k=1}^{n} f(\xi_k)\Delta x_k. \qquad (13)$$

8. Smail, L. L., "Calculus", New York: Appleton-Century -Crofts, Inc, 1949.

Since the total unit cost is the summation of all the points on the curve in an interval of $\Delta x_k$ then if $\Delta x_k = 1$ the cost per unit must be equal to $f(\xi_k)$ and the total unit cost is then

$$TUC = \sum_{k=1}^{n} f(\xi_k) \Delta x_k. \qquad (14)$$

$$TUC = \sum_{k=1}^{n} AX^B \qquad (15)$$

where $k=1 = a$ and $n = b-a+1$

Substituting into equation 12

$$TUC = \int_{a'}^{b'} f(x)dx \qquad (16)$$

where $b' = b + \Delta X$ and $a' = a - \Delta X$ .

From analysis it was found that by using a $\Delta X' = .5$ gives the best results.

Therefore,

$$TUC = \int_{a'}^{b'} f(x) \; dx = \int_{a-.5}^{b+.5} f(x)dx. \qquad (17)$$

Substituting and integrating we get

$$TUC = \frac{Ax^{B+1}}{B+1} \Bigg|_{a' = a - .5}^{b' = b + .5} \qquad (18)$$

Equation 18 can be used to compute a reasonably accurate TUC for any lot size where a is the first unit of the lot and b is the last unit of the lot.

Therefore, the AUC can be found from equation 19

$$AUC = \frac{TUC}{n} \quad \text{when } n = b - a + 1 \qquad (19)$$

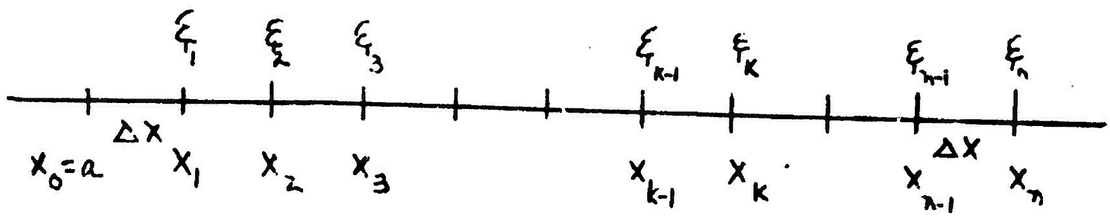

FIGURE D-3

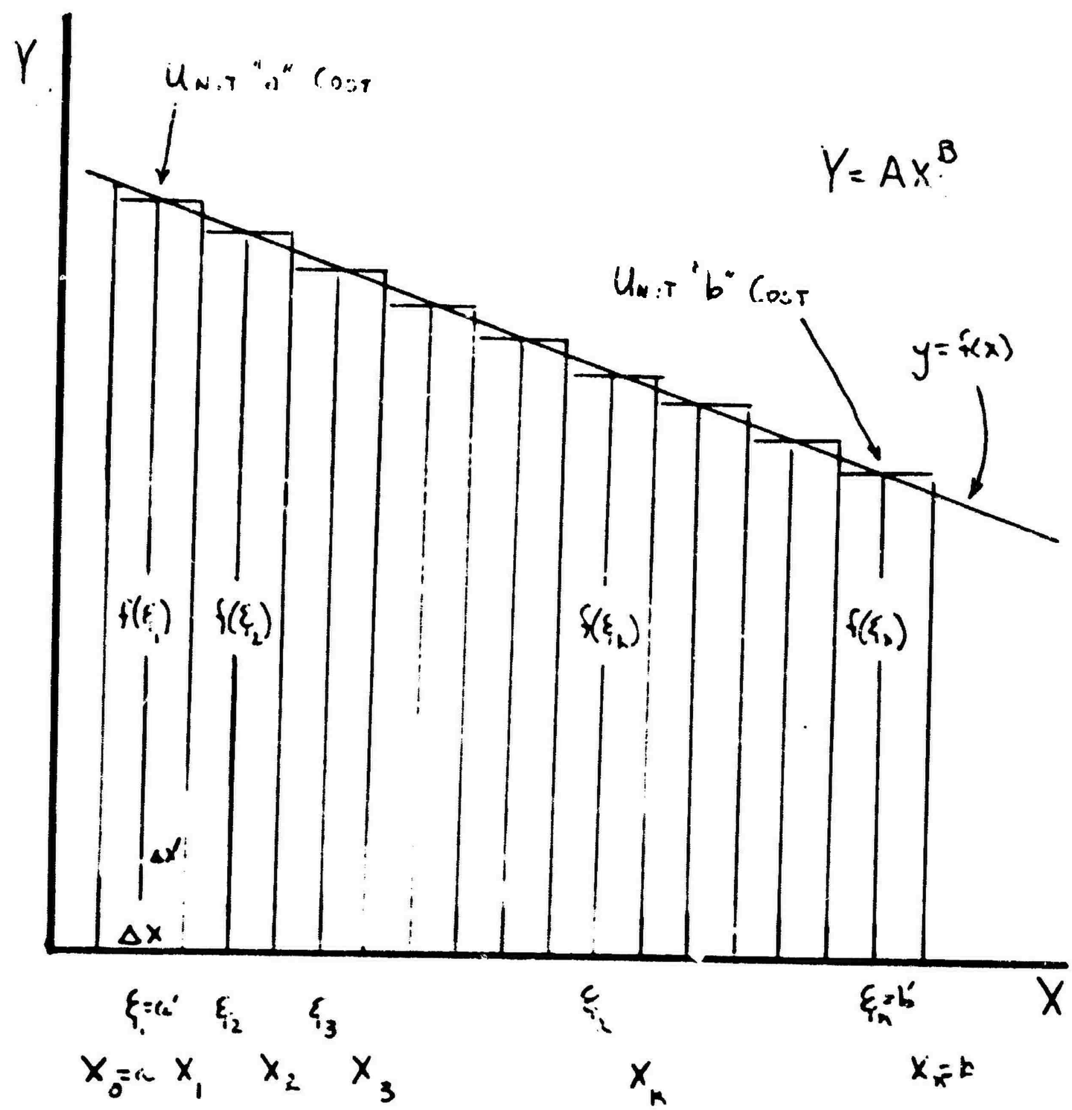


FIGURE D-4

## ALGEBRAIC LOT MIDPOINT METHOD

Another method of computing the total unit cost is to use the algebraic lot midpoint. This concept states that there is a unit in the lot which has the property of yielding the total lot cost when the cost of this unit is multiplied by the number of units in the lot. The actual cost of this unit may differ from the average cost. Mathematically, this method is related to the Mean-Value Theorem for Integrals. This theorem states that if f(x) is continuous in an interval (a,b), then there exists a number $\xi$ such that

$$\int_a^b f(x)dx = f(\xi)\ (b-a) \tag{20}$$

where $a \leq \xi \leq b$. The algebraic midpoint can be computed from [6,7]

$$K = \left[\frac{L(1+B)}{b^{(1+B)} - a^{(1-B)}}\right]^{-\frac{1}{B}} \tag{21}$$

Where K = algebraic midpoint

b = last unit of the lot +.5

a = first unit of the lot -.5

L = lot size, n = b-a+1

B = exponent of the slope.

Using the midpoint the TUC can be computed as

$$Y(K) = AK^B, \tag{22}$$

$$TUC = Y(k) \times (b-a+1) \tag{23}$$

were b-a+1 = n. Therefore the AUC can be found by equation 24.

$$AUC = \frac{TUC}{n} \tag{24}$$

6. US Army Electronics Command, "Army Programs Basic Techniques of the Learning Curve", ECOM 11-5, Volume 3, 25 June 1971

7. US Army Missile Command, "The Experience Curve Table", Vol. I & II, Redstone Arsenal, Alabama, September 1962.

When there is a computer program available, the methods of using the cumulative total factor (CTF) or cumulative average factor (CAF) are the most accurate. However, the last two methods can be done by hand computation and they will give relatively fast and accurate results.

## APPENDIX E

## FLOATS FOR A GIVEN PROBABILITY OF OUTAGE

The computation for providing sufficient floats so that a given probability exists that the spares will be sufficient to cover the average number of failures is based on the method in TM 38-715-1[9], Provisioning Techniques. (The cost of initial provisioning is often estimated by using a percentage of the yearly procurement. However, to cost initial provisioning in this manner does not reflect the advantage of increased reliability of the equipment and would provide excessive spares outage protection.) Therefore:

$$UFA = AUF + A\sqrt{AUF} \qquad (1)$$

Where UFA = float to assure availability to a given percent of the time,

AUF = average number of spares required in the supply cycle.

The

$$AUF = HOW \times PS1 \times QB \times PD \div MTBF \qquad (2)$$

where

HOW = hours of operation per day/wartime to direct support level at onset of wartime emergency

PSI = Period required to set up the supply pipeline

QB = Quantity of units to satisfy the requirement

PD = Percentage of units deployed

MTBF = mean-time-between-failures

The factor $A\sqrt{AUF}$ determines the additional number of spares required to guarantee a specific safety factor (SF), e.g., 85 percent.

The number of floats required to assure that there will be no float outage with a confidence of a safety factor can be calculated using the binominal distribution. The number of spares would be chosen in order that the probability of $\leq$UFA failures will be $\leq$ SF/100 as shown in equation 3.

$$\sum_{UFA=0}^{UFA} QB \quad p^{UFA} \quad (1-p)^{QB-UFA} \leq SF/100 \qquad (3)$$

9. TM 38-715-1, "Provisioning Techniques", US Army, October 1965.

where p = probability that one set failes, a set failure occurring at random

p = HOW x PS1 $\div$ MTBF.

If n is large and p is small the Poisson distribution closely approximates the binominal distribution. The Poisson distribution is

$$p\ (UFA) = \frac{\lambda^{UFA} e^{-\lambda}}{UFA!} \qquad (4)$$

where p (UFA) = probability that exactly UFA spares are required.

$$\lambda = AUF$$

and the standard deviation

$$\sigma = \sqrt{\lambda} = AUF.$$

Therefore, A is the number of standard deviations above the mean that will provide a given safety factor SF that the number of failures will not exceed the number of spares.

The normal distribution is also a close approximation of the binominal distribution provided n is large and neither p nor q is close to zero. Beyond an expectation of 100 events, the provisioning of floats is based on a normal curve with the variance equal to the mean. Therefore,(10)

$$P\ (X \leq b) = F(b) = \Phi\left(\frac{b-u}{\sigma}\right) = SF \qquad (5)$$

where $b = \mu + A\sigma = \mu + A\sqrt{\mu}$

By substitution we get

$$P\ (X \leq u + A\sigma) = \Phi(A) = SF \qquad (6)$$

Solving for A for various SF we get,

| Protection Level,% | A |
|---|---|
| 75 | 0.67 |
| 85 | 1.04 |
| 95 | 1.65 |
| 99 | 2.33 |

10. Kreyszig, E., "Advanced Engineering Mathematics", New York: John Wiley & Sons, Inc., 1962.

## APPENDIX F

## LCC MODEL AND OUTPUT

The Life Cycle Cost Model program is written in FORTRAN for the Burroughs B5700 FORTRAN Compiler. The program is divided into three major sections- Input, Internal and Output.

The Internal and Output sections are stored on tape and the Input section is on cards. (Both the tape and cards are necessary for the program to run.) Putting the input section on cards gives the user an easy method of providing the different input data for each LCC analysis that is made.

The program is capable of computing the LCC of up to nine separate equipments plus computing the totals from each N separate equipments into a composite. All the input data necessary for the program to run is entered in the input section except for the names of each equipment. These names are supplied as separate data cards and inserted after the card "DATA CARDS" at the end of the deck.

The program calculates all cost elements for the N (N is equal to or less than 9) equipments considered and stores the costs in arrays. When all costs are computed for the N equipments an output is generated in the format shown in Figure F-1.

The CHK option provides the user with a detailed listing of all the cost elements and input variables necessary to compute these elements as shown in Figure F-2.

When the program is run for current equipment which is considered to be fully fielded only the Attrition element of the Investment Recurring category and the Operating Cost category will be outputted with a note to that effect.

For each output the program generates a Work Breakdown Structure Table (as discussed in Appendix A) as shown in Figure F-3 and a listing of the input data.

The program has the capability of doing an immediate sensitivity analysis of the cost based on the variation of the MTBF by $\pm$ 30 percent of the given MTBF.

The program is available from the Combat Radio Systems Team, Net Radio Technical Area, Communications/ADP Laboratory.

15 YEAR LIFE CYCLE COST RECEIVER TRANSMITTER/BTA

| | | |
|---|---|---|
| **RESEARCH AND DEVELOPMENT** | | |
| ENGINEERING | 13450000. | |
| PROTOTYPE FABRICATION | 4200000. | |
| SYSTEM TEST AND EVALUATION | 1600000. | |
| DATA | 500000. | |
| TOTAL SYSTEM MANAGEMENT | 4750000. | |
| TRAINING | 60000. | |
| PRODUCIBILITY ENGINEERING AND PLANNING | 600000. | |
| SUBTOTAL | | 25160000. |
| **INVESTMENT NONRECURRING** | | |
| INITIAL PRODUCTION FACILITIES | 1250000. | |
| DATA | 180000. | |
| TOOLING | 1200000. | |
| INSTRUCTOR TRAINING | 70000. | |
| TOTAL SYSTEM MANAGEMENT | 3000000. | |
| SUBTOTAL | | 5700000. |
| **INVESTMENT RECURRING** | | |
| HARDWARE COST(END ITEMS) | 171273531. | |
| ATTRITION(END ITEMS) | 14803509. | |
| INITIAL SPARE AND REPAIR PARTS | 17271619. | |
| SUPPORT EQUIPMENT | 2079000. | |
| AUXILIARY ITEMS | 22267343. | |
| FIRST DESTINATION TRANSPORTATION | 3416626. | |
| INITIAL TRAINING | 60000. | |
| ENGINEERING CHANGES | 3719425. | |
| SYSTEM TEST AND EVALUATION | 2750000. | |
| TOTAL SYSTEM MANAGEMENT | 15000000. | |
| SUBTOTAL | | 452721133. |
| **OPERATING COSTS** | | |
| PERSONNEL, PAY AND ALLOWANCES | 12462675. | |
| PERSONNEL, REPLACEMENT TRAINING | 7036305. | |
| CONSUMPTION | 43134774. | |
| INTEGRATED LOGISTICS SUPPORT | 13514023. | |
| DEPOT OVERHAUL | 17404395. | |
| TRANSPORTATION | 983714. | |
| SUBTOTAL | | 91600006. |
| **TOTAL LIFE CYCLE COST** | | 57[illegible]106019. |

NOTE-BATTERY COSTS ARE INCLUDED, ANNUAL BATTERY CONSUMPTION COST IS 2899200.

NOTE-LCC CALCULATED FOR 100 PERCENT OF THE BASELINE MTBF

NOTE- NUMBER OF FULLTIME REPAIRMEN REQUIRED PER YEAR TO SUPPORT THE EQUIPMENT 37.30

FIGURE F-1

DETAIL COST CHECK RADIO, APPLIQUE

MODE 0.00 INVESTMENT NONRECURRING= 0.00

INVESTMENT RECURRING-HARDWARE COST

SLOPE= -0.23447 AUF= 11679.47 UFA= 11024.20 AUC= 1373.07

[illegible] CTF= 3574.750737 CAF= 0.005567

LAH 1505 CTFB= 297.997021 CAFB= 0.257037

HTJC= 137104577.15 DAJV= 0.00 DDTYC= 0.00

INVESTMENT RECURRING-INSTRUMENTATION

MISARC= 21021714.80 DISC= 16572712.95 DISBO 0.00 DOPC= 35109283.55

DATC= 62376209.55 RSA= 41634.30 CAF= 0.0630100639 AUCY= 1011.45

DFDC= 2350908.40

TOTAL INVESTMENT RECURRING= 203290236.49

OPERATING COSTS

MANPAT= 35134_0.74 [illegible] 0.00 [illegible] 351043.47

MRTC= 503546.40 DDRT= 0.09 [illegible] 60054.09

[illegible] 2740005.40 [illegible] 0.00 [illegible] 470480.09

[illegible] 0.00 [illegible] 0.00 [illegible] 82131.9[illegible]35

TOTAL OPERATING COSTS= 13985704.09

INPUT=

COMMON [illegible] [illegible]

OPERATIONS 1 [illegible] 1 DEPOT [illegible] 1 INT LOG SPT 1

OPTIONS [illegible]

INITIAL SPARES [illegible] CONSUMPTION [illegible] REPAIR PARTS [illegible]

REPAIR PARTS DATA

[illegible] [illegible] [illegible] 354.330030 [illegible] 0.100000 [illegible] 0.0[illegible]0000

INITIAL SPARES DATA [illegible] 47.230030 [illegible] 2.350000

COMPUTATION DATA

[illegible] 13 [illegible] 345.399349 [illegible] 12.000000 [illegible] 3.000000

[illegible] [illegible] [illegible] 100332.833033 [illegible] 46350.000000 [illegible] 1.900000

[illegible] 2.695394 [illegible] [illegible] [illegible] 0.333050 [illegible] 74

[illegible] [illegible]

FIGURE F-2

15 YEAR LIFE CYCLE COST RECEIVER TRANSMITTER/RTA

| | APPROPRIATION | MAJOR SYSTEM EQUIPMENT | ALL OTHER | INITIAL SPARES/ REPAIR PARTS |
|---|---|---|---|---|
| RESEARCH AND DEVELOPMENT | RDTE | 17650000. | 6620000. | 600000. |
| INVESTMENT NONRECURRING | PEMA | 2450000. | 200000. | 0. |
| INVESTMENT RECURRING | PEMA | 215270255. | 3110185. | 17530693. |
| INVESTMENT RECURRING | MPA OMA OTHER | 0. | 16810000. | 0. |
| INVESTMENT NONRECURRING | MPA OMA OTHER | 0. | 3050000. | 0. |
| RESEARCH AND DEVELOPMENT | MPA OMA OTHER | 0. | 290000. | 0. |
| OPERATING | OMA MPA OTHER | 89570581. | 2036305. | 0. |

FIGURE F-3